COMPLETION REPORT

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PHASE I. POPULATION DYNAMICS

PART I. THE MIGRATION AND GROWTH OF DUNGENESS CRAB (Cancer magister) IN SOUTHEASTERN ALASKA

By

Carl Lehman

INTRODUCTION

Commercial utilization of Dungeness crab (Cancer magister) in Alaska has existed since the early 1900's with use in the early days of the fishery devoted almost entirely to supplying local demand. In Southeastern Alaska the Dungeness fishery has centered in the Petersburg-Wrangell area though the species are taken elsewhere in the region. Commercial catch of Dungeness for all Southeastern Alaska for a 7-year period is shown in Table 1, with the average annual catch for the period amounting to 3,224,550 pounds.

Table 1. Dungeness crab catch, Southeastern Alaska (in pounds)

1960	1,993,167
1961	1,695,015
1962	3,922,988
1963	4,679,661
1964	4,633,240
1965	3,302,670
1966	2,345,113

Biological information on Dungeness crab in Alaska is scanty and in 1963 a tagging program was initiated as the first step in collecting biological information on behavior, growth, and migration patterns necessary for proper management. Of the several recognized crab fishing grounds in the Wrangell-Petersburg area, Duncan Canal, one of the largest and most productive, was chosen as the focal point of the crab tagging project. Duncan Canal and neighboring crab fishing areas in the Wrangell-Petersburg area are shown in Figure 1. Other recognized fishing grounds are scattered throughout Southeastern Alaska but are not pertinent to this report.

In the Southeastern portion of Alaska the terms "stock" and "breeding population" are probably not synonymous. The term stock refers to an aggregation of crab contained within a certain area and does not imply that any stock described is a separate breeding population. Due to the planktonic nature of the early life history of these crustaceans it is entirely probable that there is a considerable exchange of individuals between stocks until the larvae settle to the bottom. As a result, the term stock as used in this paper refers only to that portion of the crabs life history in which it is a bottom dwelling creature. The breeding population in the study area probably contains several stocks. No attempt is made herein to describe breeding populations as this is beyond the scope of this project.

METHODS

Crabs used in this project were obtained from commercial fishermen and from commercial crab pots fished by the author. The Alaska Department of Fish and Game vessel M/V KITTIWAKE, a 72-foot boat equipped with pot lifting gear, was used in the project when available. Damaged crabs, or those judged too soft for tagging, were excluded from the program because of poor survival potential. Each crab tagged and released was measured, with the tag number, sex, size, and shell condition noted. Measurement was taken with stainless steel calipers to the nearest tenth millimeter across the dorsal surface of the carapace just anterior to the tenth antero-lateral spines. In addition the location and depth of the release area was noted.

Tagging

Crabs were tagged by placing the anterior end of each specimen in a small shallow box such that the chelae were immobilized. Two holes were punched one half inch apart on the demersal line and at the posterior end of the carapace. A red plastic "spaghetti" type tag imprinted with ADF&G and a serial number was threaded through the two holes. The two ends of the tag material were tied together forming a loop through the two holes and leaving two easily discernible "pigtails". This method of tagging was developed and used by the State of Oregon (Snow and Wagner, 1965).

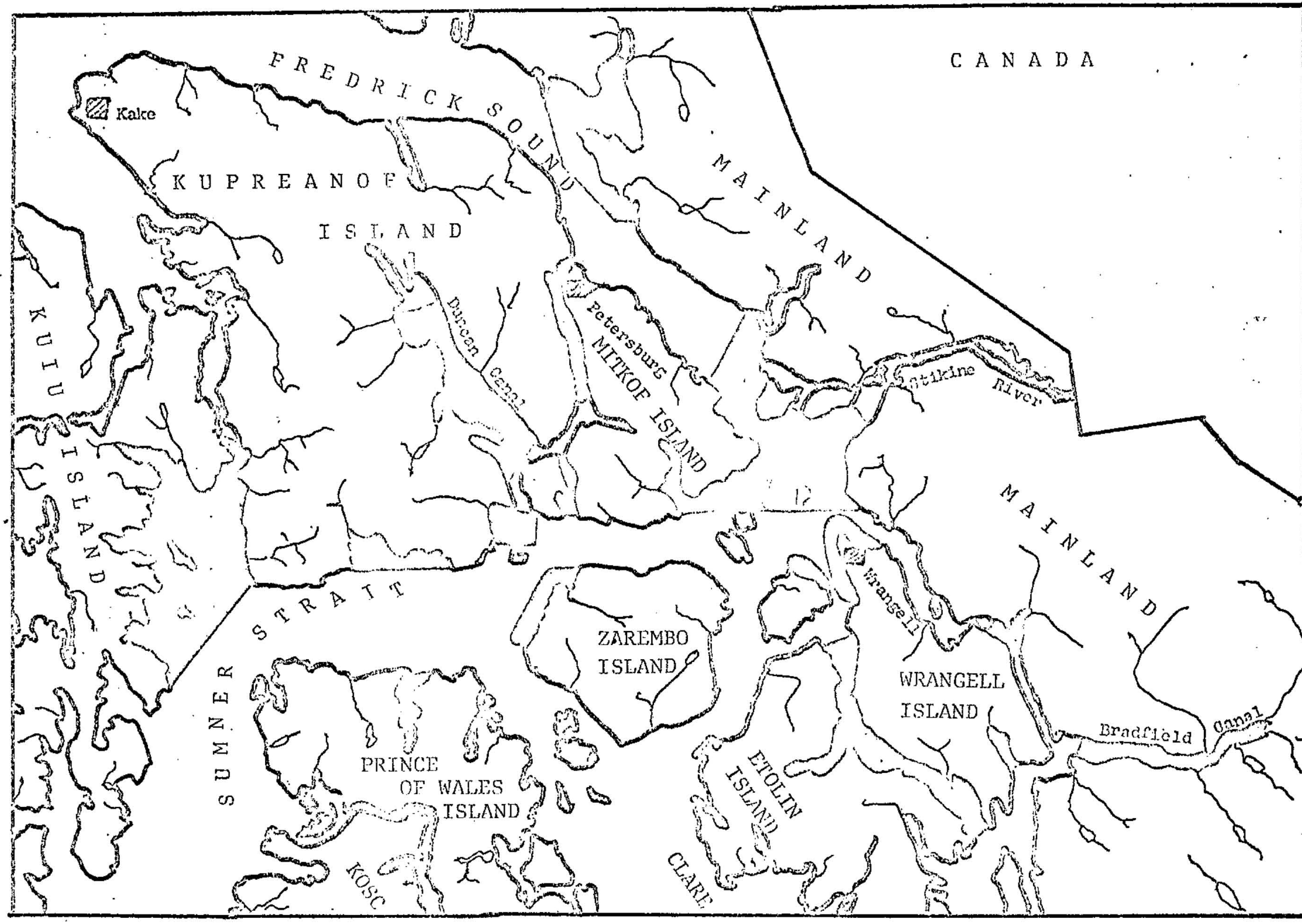

Figure 1. Chart of general area covered by 1963-1964 Dungeness crab tagging project. Darkened areas are major crab fishing grounds

Captured crabs were tagged and liberated the same day with the exception of one group of approximately 200 individuals. These were held overnight in a live-car hung over the side of the M/V KITTIWAKE to assess immediate mortality due to tagging. No mortalities occurred during this period and losses from handling or tagging were therefore judged extremely light.

Tag recovery

In common with many tagging programs this project depended almost entirely upon industry members for tag returns. Fishermen and cannerymen were contacted frequently, and a reward of $1.00 was paid for each tagged crab returned when accompanied with information on the location and depth in which the crab was taken, and the date of its capture.

Tagged crab returned to project personnel alive were released again whenever possible. Examination of the holes in the crab carapace through which the tag was threaded indicated whether or not the animal had molted since original tagging and release. If in the interim, the crab had not molted the holes punched in the carapace remained sharply defined. Crabs that had molted between the time of original release and subsequent recapture were recognized by the edges of the holes appearing smooth and somewhat molded around the plastic material of the tag. Notations were made on all recaptured crabs. Information taken included growth, time at large, and data on area of capture.

RESULTS

From June of 1963 through 1964 a total of 2,066 male and 433 female Dungeness crab bearing serially numbered tags were released in 25 different locations. Except for one area concerned with a release made on the east side of Annette Island near Ketchikan and from which no returns were obtained, release points are shown in Figures 2A, 2B, 2C, 3 and 4. For clarity three copies of a chart showing the same geographic area (Figures 2A, 2B, and 2C) are used to show dispersion of tagged crab from 16 numbered release points. Arrows associated with each release point show only the pattern of dispersal and do not necessarily indicate the number of returns. Release points, numbered 1 through 16 are used in Table 2 where the notation "2A-9", for example, indicates Figure 2A, release point 9.

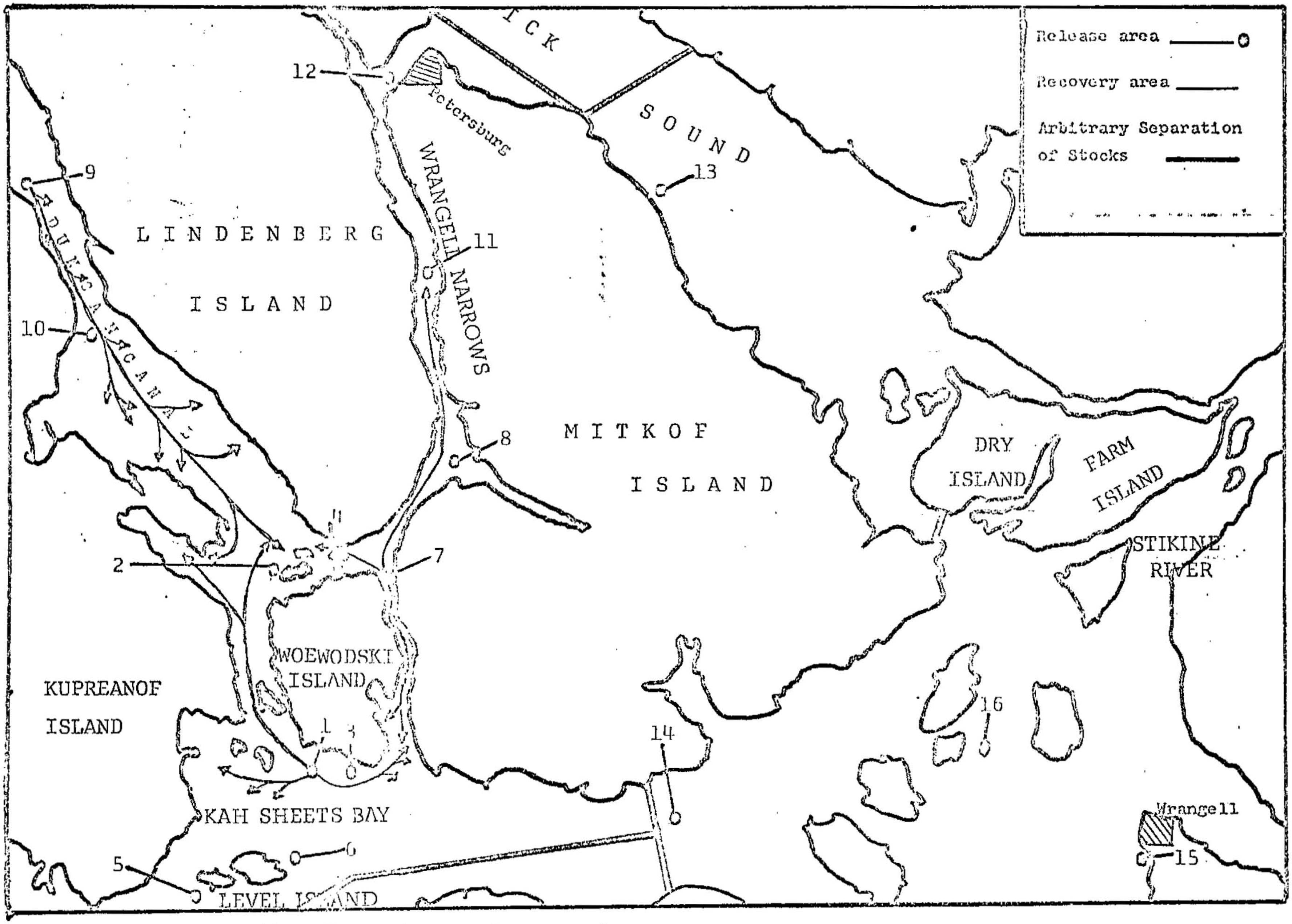

Fig. 2-A Wrangell - Petersburg release and recovery areas

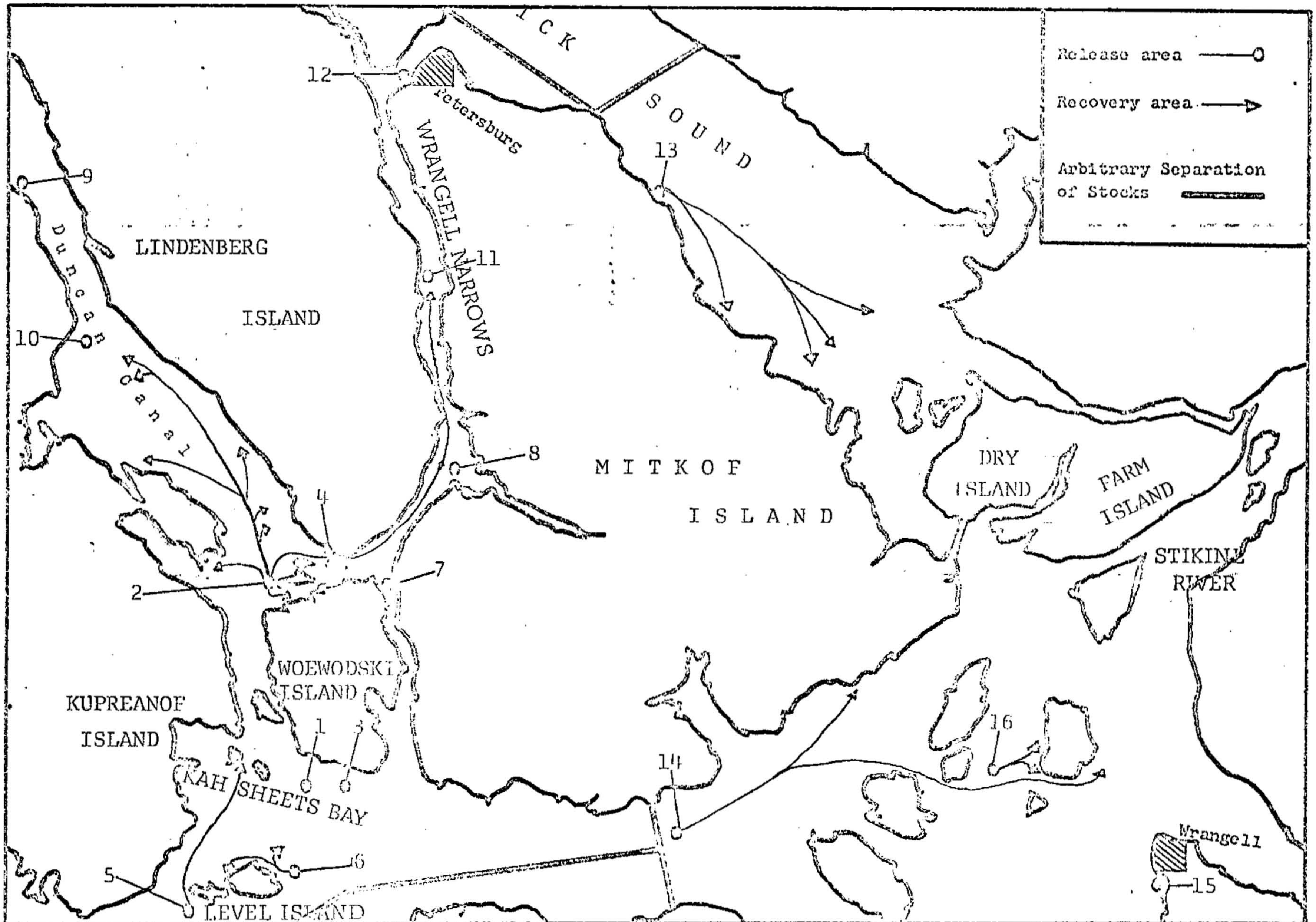

Fig. 2-B Wrangell - Petersburg release and recovery areas

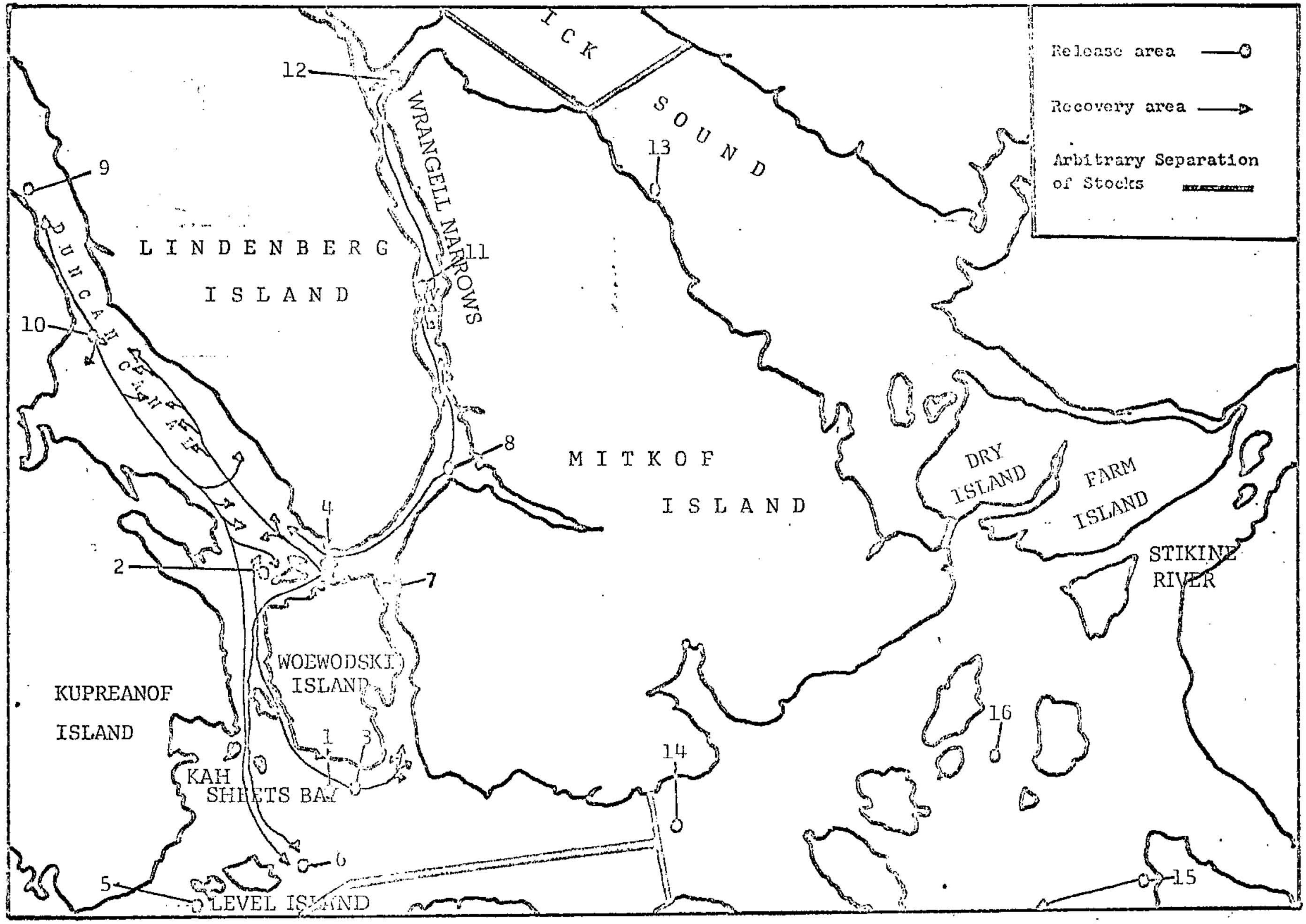

Fig. 2-C Wrangell - Petersburg release and recovery areas

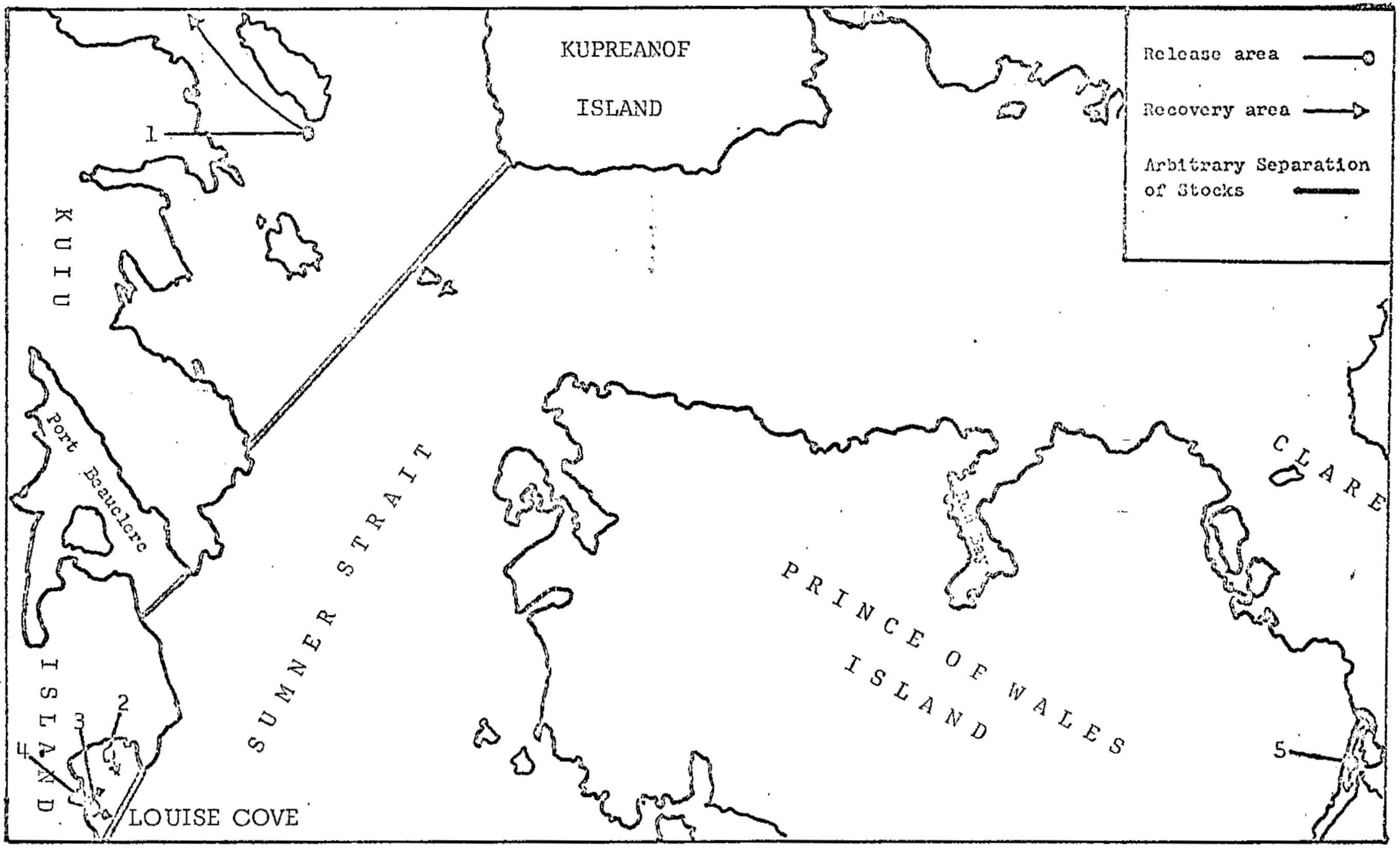

Fig. 3 Sumner Strait - Exchange Cove release and recovery areas

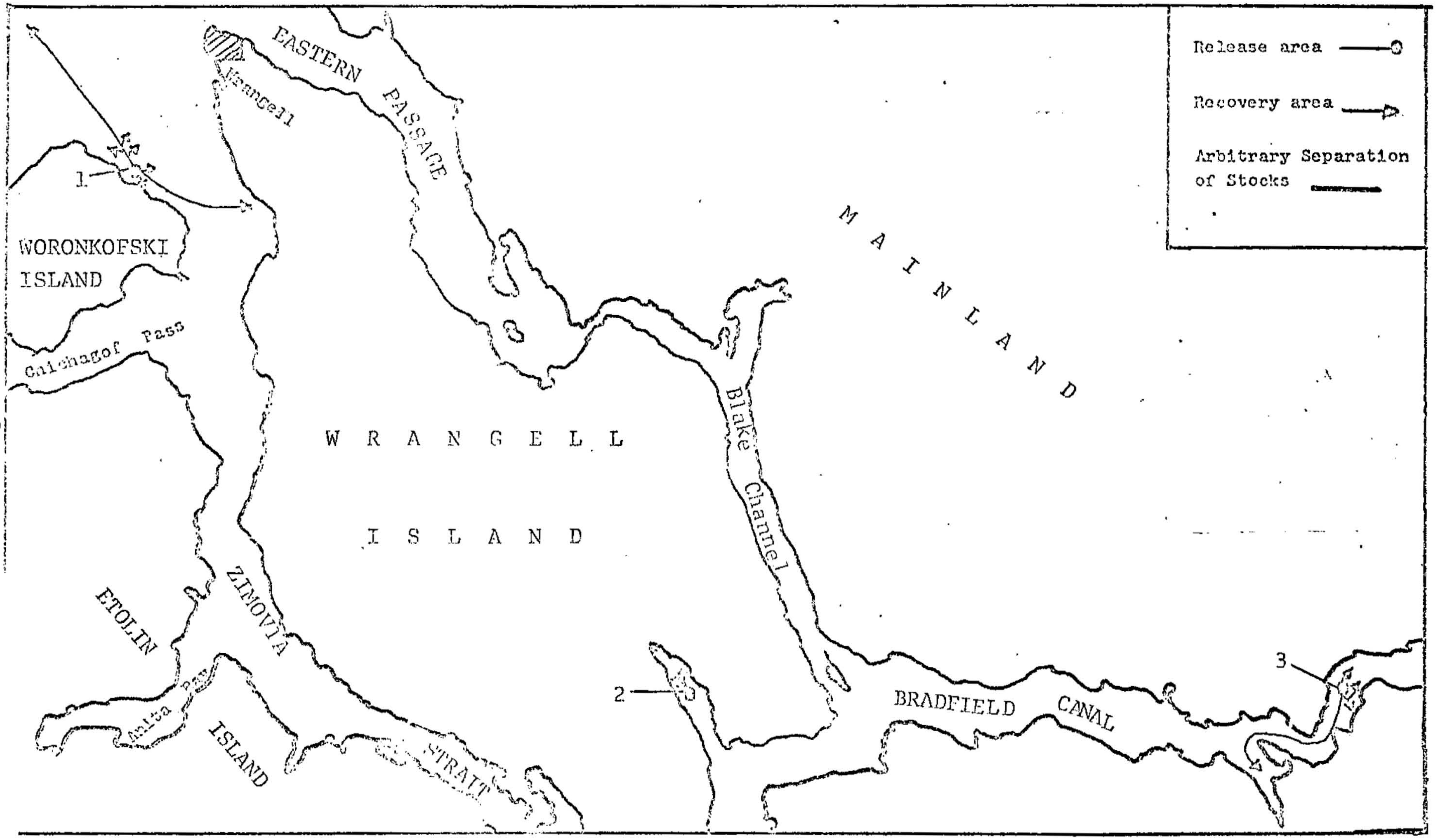

Fig. 4 Bradfield Canal - Wrangell release and recovery area

Table 2. Dungeness crab released and recovered by release area.

See figure	Number released F	Number released M	Date released	Number Recaptured F	Number Recaptured M	Percent recovery F	Percent recovery M	Percent total
2A-1	12	106	06-29-63	1	15	8.3	14.1	13.5
2A-7	52	125	07-12-63	2	11	3.9	8.7	7.3
2A-9	5	100	07-15-64	2	25	40.0	25.3	26.0
2B-2	64	139	06-30-63	7	21	10.9	15.1	13.9
2B-5	27	43	07-11-63	1	1	3.7	2.3	2.9
2B-6	66	20	07-14-64	3	3	4.5	15.0	4.7
2B-13	15	103	02-19-64	0	33	0	32.0	28.0
2B-14	3	56	02-14-64	0	5	0	8.9	8.5
2B-16	35	53	07-16-64	0	8	0	15.4	9.2
2C-3	23	61	06-30-63	0	6	0	10.0	7.1
2C-4	24	65	07-01-63	1	12	4.2	16.7	13.0
2C-8	30	7	07-14-64	2	2	6.7	28.6	10.8
2C-10	8	41	07-15-64	2	17	25.0	41.5	38.8
2C-11	0	58	01-31-64	-	20	-	34.5	34.5
2C-12	9	42	02-18-64	0	4	0	9.5	7.8
2C-15	6	211	02-03-64	0	3	0	1.4	1.4
3-1	17	115	11-08-63	0	4	0	3.5	3.0
3-2	1	95	11-18-63	0	18	0	18.9	18.8
3-3	0	52	11-19-63	-	7	-	13.5	13.5
3-4	0	9	11-19-63	-	9	-	23.7	23.7
3-5	2	148	01-30-64	0	30	0	20.3	20.0
4-1	14	66	07-16-64	1	16	7.1	23.9	21.0
4-2	8	150	02-08-64	0	2	0	1.3	1.3
4-3	6	82	02-06-64	0	4	0	4.9	4.5
Annette Island	6	89	03-04-64	0	0	0	0	0
Total	433	2,066*		22	276	5.0	13.2	11.8

* Does not include 48 tagged crabs rereleased after capture in various areas.

Migration patterns

In all cases the shortest water route between the point of release and the recovery area was plotted. This means, of course, that the distances traveled, as reported in Tables 3 and 4 are subjective measurements and may be meaningless in the case of individuals. These measurements for distance traveled although somewhat arbitrary, do serve to indicate that post-larval crabs probably do not migrate long distances in the inside waters of Southeastern Alaska. It is thought that this is due to the discontinuity in Dungeness crab habitat that is so noticeable when one examines the geography of this area since the species prefers a mud or sand bottom and is generally found in areas of 50 fathoms or less. The heavy black lines in Figures 2A through 4 are proposed boundaries of the various stocks of Dungeness crabs in the area under consideration. These lines are sketched in using the pattern of movement and bottom topography as the criteria.

Louise Cove (Figure 3) and the head of Bradfield Canal (Figure 4), each seem to have small separate stocks. The north side of the Stikine River flats and the south side of the same area also appear to contain separate stocks (Figure 2B - 13, 14, 16). These areas near the Stikine River mouth are connected by the sandy and muddy grounds that Dungeness crab prefer but are separated by a shallow water spot of extremely low salinity. This low salinity may be the "fence" between these two closely adjacent areas. Duncan Canal, Wrangell Narrows, Kah Sheets Bay, and Level Islands constitute a single stock of crab (Figures 2A, 2B, 2C). This area represents a single, unbroken, crab habitat. Although it is made up of numerous waterways and channels, crabs are able to move throughout the area without encountering any major barriers. No mass migrations were indicated during the course of this project, but local fishermen state that they have noted occasional phenomena that might be considered mass migration in some areas. Additional tagging is required over a longer period of time to discover if this occurs.

Movement and behavior associated with the life history of the species

In addition to the horizontal movement of crabs there appeared to be a regular onshore and offshore vertical migration that occurred annually. About May, the males start moving upward into shallow water (generally 10 fathoms or less) while females remain in depths greater than 10 fathoms. Throughout the summer this depth stratification was maintained. During May a molt occurs involving pre-recruit males in the 140-164 mm category. After molting these males will achieve harvestable size but will be in soft shell condition for some 4-6 weeks. In a heavily fished area such as Duncan Canal this spring molt provides the bulk of the fishery each year.

By the latter part of September the males and females are found together signifying the beginning of the mating season. After the mating season the crabs were usually found in depths greater than those encountered during the summer months. Variations in timing as great as a month in the aforementioned scheme may occur depending upon the area and the year. In addition to seeking waters of greater depths in the winter, SCUBA observations indicate that both males and females spend a great portion of their time buried in the bottom sediments. This behavior may serve as some protection from colder waters and predators during this period of apparent dormancy.

During the mating season in the latter part of September, the majority of Dungeness females molt. Females must be in a soft-shell condition for successful mating to occur and in mid-October ovigerous females laden with bright orange colored eggs begin to appear. The eggs grow progressively darker until they are a very dark brown and are ready to hatch. By the end of May, egg bearing females are rarely found, indicating larval release has occurred.

Tag recoveries and tag loss

The percent of tag recovery (Table 2) was relatively poor with only a 5.0 percent return from females and a 13.2 percent recovery from males. However, groups of tagged crabs were placed in areas not normally fished in an attempt to determine if crabs from unfished areas were contributing to adjacent commercial fisheries. Such contributions were low as shown by returns from 2A-7, 2B-5, 2B-14, 2C-15, 3-1, 4-2, and Annette Island, and tended to limit the total percentage of recovery. Elimination of these groups brings the returns for tagged females to 6.0 percent and males to 19.4 percent. Preliminary work indicated that the tag loss from females may be as high as 20 percent while males shed a relatively low 7 percent. It is postulated the higher loss on females derives from handling in the soft-shell state by males during the mating process. Such a tag loss would, of course, contribute to the overall low percentage of tag returns.

In Table 3 release and recovery measurements are grouped by 5 mm increments of carapace width. All of the males included in the category of 165 mm and over are crabs that are available (legal size) to the commercial males only fishery. Conversely those 164 mm and less are not available (sub-legal size) to commercial fisheries. The recovered sub-legal crabs were at large an average of 12.2 months and moved an average of 3.2 miles. By comparison, legal crabs were out 7.1 months and traveled an average of 2.4 miles. The difference in distance traveled between the two groups is probably not significant. The difference in average number of months out between sub-legal and legal tagged crabs may be due to commercial exploit-

Table 3. Numbers of crabs in 5 millimeter increments tagged, recovered, and molted, with distance traveled and time out.

MALES

Size class when tagged mm	Number tagged	Number received	Percent	Number molted	Months out Average	Months out Range	Miles traveled Average	Miles traveled Range
			Sub-legal					
120-124	1	0	0.0	0	-	-	-	-
125-129	5	0	0.0	0	-	-	-	-
130-134	5	0	0.0	0	-	-	-	-
135-139	13	1	7.6	1	14.0	-	0.0	-
140-144	45	0	0.0	0	-	-	-	-
145-149	48	2	4.1	2	16.5	15.0-18.1	1.5	0.0- 3.0
150-154	163	13	8.0	13	16.3	6.2-37.9	2.5	0.0-10.0
155-159	354	49	13.8	30	14.0	0.3-32.9	4.0	0.0-27.0
160-164	406	60	14.8	24	9.7	0.3-24.0	2.8	0.0-10.5
			Legal					
165-169	203	22	10.8	2	8.3	0.9-17.7	2.5	0.0-12.5
170-174	207	20	9.7	0	7.1	0.3-18.4	.9	0.0- 5.9
175-179	163	31	19.0	1	7.6	1.0-15.8	3.2	0.0-14.5
180-184	171	25	14.6	0	6.2	0.7-16.9	2.8	0.0- 9.5
185-189	127	18	14.2	0	7.6	2.3-17.1	3.0	0.0- 7.5
190-194	103	18	17.5	0	8.4	1.5-14.3	1.9	0.0- 7.5
195-199	61	12	19.7	0	5.4	0.7-10.6	2.6	0.0-12.5
200-204	24	2	8.3	0	8.6	8.6- 8.6	0.5	0.0- 0.
205-209	10	2	20.0	0	4.8	1.3- 8.3	0.5	0.0- 0.
210-214	3	1	33.3	0	0.9	-	1.0	-
215-219	2	0	0.0	0	-	-	-	-
Total	2,114	276	13.2	73	7.5		2.8	

FEMALES

Size class when tagged mm	Number tagged	Number received	Percent	Number molted	Months out Average	Months out Range	Miles traveled Average	Miles traveled Range
115-119	1	0	0.0	0	-	-	-	-
120-124	6	1	16.7	0	11.8	-	5.5	-
125-129	9	0	0.0	0	-	-	-	-
130-134	12	0	0.0	0	-	-	-	-
135-139	18	0	0.0	0	-	-	-	-
140-144	24	0	0.0	0	-	-	-	-
145-149	47	2	4.3	0	18.8	12.7-25.0	6.0	5.0- 7.
150-154	106	4	3.8	1	21.4	9.6-49.5	6.0	5.0-13.
155-159	107	8	7.5	0	16.1	10.6-37.1	1.7	0.0- 4.
160-164	73	4	5.5	0	7.7	1.2-14.1	2.0	0.0- 5.
165-169	24	2	8.3	0	19.0	13.8-24.3	3.3	1.0- 5.
170-174	4	0	0.0	0	-	-	-	-
175-179	2	1	50.0	0	12.5	-	2.0	-
Total	433	22	5.0	1	15.7		3.2	

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ation since fishermen will generally leave areas where only small quantities of legal males are being caught. As the majority of sub-legal crabs did not generally inhabit the same areas as the legal males it would then be approximately a year before the previously sub-legal pre-recruit males would be captured by the commercial fishery. In the following section on growth it will be shown that the majority of pre-recruit males (140-164 mm) molt annually and at that molt achieve the legal size of 165 mm or greater. The fact that the pre-recruit group was out an average of only 12.2 months shows that these crabs were taken soon after they achieved legal size. Of the tagged males returned 55 percent of the pre-recruit group had molted and had become available to the fishery during the 12.2 months they were at large.

Growth

Tags used as previously mentioned, are capable of remaining in place through one or more molts thus making it possible to obtain growth data. Table 4 contains such data obtained from 73 males and 1 female. The female is the only one of the sex recovered after molting and is included only for the purpose of comparing her growth with that of males of the same pre-molt shell size. A male that molts at 154 mm will increase to approximately 182 mm in carapace width. The one female recovery initially the same size (154 mm) achieved 170 mm in size upon molting. These figures agree well with data gathered on the south end of the Queen Charlotte Islands in Canada by Butler (1961). The difference between males and females in the amount of growth per molt at a given size indicates a different growth pattern for the two sexes. Males grow faster and reach a greater maximum size than females. The single female returned was at large after tagging for 49.5 months and shed her shell only once, thus indicating that this was probably the terminal molt. Examination of Table 3 shows the maximum size class of the females tagged as 175-179 mm which is also the maximum size class of females encountered in the normal population. If the above mentioned female had molted one more time increasing by the same increment as in the previous molt (13.9 mm), she would have achieved a size of 183.7 mm. This size would be greater than the largest female yet observed in the study and is another indication that the one female molt noted in Table 4 was a terminal ecdysis.

The growth data obtained from tagged crabs in Table 4 indicates that any male of approximately 140 mm or greater will achieve at least 165 mm or larger in one molt. The minimum legal size in the commercial fishery is 165 mm. Our growth data show that male crabs between 140 and 164 mm constitute the pre-recruit stock, and the regular occurrence of large numbers of newly molted legal males in May indicates a large portion of these pre-recruit males molt yearly and at about the same time.

Table 4. Molted tag recoveries, 1963-1964.

Males

Release		Recovery		Growth		Months at large
Size mm	Date	Size mm	Date	Increment mm	%	
138.5	2/ 8/64	161.8	4/ 8/65	23.3	16.8	14.0
145.1	2/ 3/64	170.3	8/ 5/65	25.2	17.4	18.1
146.0	7/16/64	178.6	10/15/65	32.6	22.3	15.0
150.0	7/16/64	179.0	7/00/66	29.0	19.3	24.0
150.0	7/15/64	178.8	9/18/65	28.8	19.2	14.1
*150.0	7/14/64	196.4	9/ 5/65	46.4	30.9	13.7
151.0	7/15/64	182.2	7/16/65	31.2	20.7	12.0
151.0	7/15/64	182.5	7/ 9/65	31.5	20.9	11.8
152.0	7/15/64	183.6	5/ 4/65	31.6	20.8	9.6
152.2	7/16/64	185.8	8/23/65	33.6	22.1	13.2
152.2	2/ 8/64	181.6	4/21/65	29.4	19.3	14.5
152.7	6/30/63	180.7	8/27/66	28.0	18.3	37.9
154.0	7/15/64	183.0	9/11/65	29.0	18.8	13.9
154.0	7/16/64	181.8	10/15/65	27.8	18.1	15.0
154.3	7/16/64	182.0	7/00/66	27.7	18.0	24.0
154.8	1/31/64	181.0	7/26/64	26.2	16.4	5.9
155.0	7/15/64	188.0	9/ 6/65	33.0	21.3	13.7
155.5	7/16/64	183.7	10/ 2/65	28.2	18.1	14.5
155.6	6/29/63	189.1	8/16/64	33.5	21.5	13.6
156.0	7/15/64	186.9	8/10/65	30.9	19.8	12.8
156.0	7/15/64	189.0	7/15/65	33.0	21.2	12.0
156.0	7/16/64	188.5	7/00/66	32.5	20.8	24.0
156.0	7/15/64	189.7	8/22/65	34.7	22.3	13.2
156.3	7/15/64	187.5	6/10/66	31.2	20.0	22.8
156.3	6/30/63	190.0	6/24/64	33.7	21.6	11.8
156.4	6/29/63	187.4	4/30/65	31.0	19.8	22.0
156.8	7/16/64	185.8	4/13/67	29.0	18.5	32.9
157.0	7/16/64	188.0	8/11/65	31.0	19.7	12.8
157.2	6/29/63	182.5	12/ 9/64	25.3	16.1	17.3
157.4	7/16/64	190.2	8/23/65	32.8	20.8	13.2
157.4	7/15/64	186.5	8/10/66	29.1	18.5	24.8
157.7	1/31/64	182.8	10/13/64	25.1	15.9	8.4
157.8	7/16/64	184.4	10/20/66	26.6	16.9	27.1
158.0	7/15/64	190.4	9/ 4/65	32.4	20.5	13.6
158.0	7/15/64	188.3	7/30/65	30.3	19.2	12.5
158.4	7/15/64	189.3	8/10/65	30.9	19.5	12.8
158.6	7/15/64	187.0	10/ 5/65	28.4	17.9	14.7
158.6	7/15/64	182.7	6/ 2/65	24.1	15.2	10.6

* Two molts

Table 4. Molted tag recoveries, 1963-1964 (cont.)

Males

Release		Recovery		Growth		Months at large
Size mm	Date	Size mm	Date	Increment mm	%	
159.0	6/29/63	193.6	8/28/64	34.6	21.8	14.0
159.0	7/15/64	183.3	9/18/65	24.3	15.3	14.1
159.0	6/15/64	182.4	6/15/65	23.4	14.7	12.0
159.0	7/15/64	186.6	8/11/65	27.6	17.4	12.9
159.0	7/15/64	187.4	7/ 9/65	28.4	17.9	11.8
159.0	7/16/64	187.2	9/28/65	28.2	17.7	14.4
159.2	7/16/64	190.5	7/00/66	31.3	19.7	24.0
159.2	7/16/64	191.7	9/20/65	32.5	20.4	14.1
160.0	7/16/64	195.8	7/00/66	35.8	22.4	24.0
160.0	7/15/64	192.3	8/ 9/65	32.3	20.2	12.8
160.0	7/ 1/63	192.0	7/15/64	32.0	20.0	12.5
161.0	7/15/64	193.7	9/23/65	32.7	20.3	14.3
161.0	7/14/64	188.9	7/ 4/66	27.9	17.3	23.7
161.1	7/ 1/63	187.8	8/25/64	26.7	16.6	13.8
161.2	7/15/64	186.3	7/14/65	25.1	15.6	12.0
161.2	7/15/64	193.1	8/11/65	31.9	19.8	12.9
161.3	2/ 6/64	181.3	5/18/65	20.0	12.4	15.3
161.4	7/14/64	190.0	5/23/65	28.6	17.7	10.3
161.4	6/29/63	193.4	5/23/65	32.0	19.8	22.8
162.0	7/15/64	197.1	6/ 7/66	35.1	21.7	22.7
162.0	7/15/64	190.5	6/ 8/65	28.5	17.6	10.8
162.0	7/15/64	188.6	8/11/65	24.6	15.2	12.9
162.0	7/15/64	195.9	8/ 1/65	33.9	20.6	12.5
162.4	7/15/64	192.3	7/ 9/65	29.9	18.4	11.8
163.0	7/ 1/63	197.5	7/16/64	34.5	16.3	12.5
163.4	7/15/64	193.0	8/16/65	29.6	18.1	13.0
163.4	7/18/64	187.6	6/ 8/65	24.2	14.8	10.8
164.0	7/15/64	189.7	6/ 2/65	25.7	15.7	10.6
164.0	7/ 5/64	190.7	8/30/65	26.7	16.3	13.5
164.2	7/15/64	194.8	6/10/66	30.6	18.6	22.8
164.3	7/15/64	189.4	8/22/65	25.1	15.3	13.2
164.6	7/15/64	195.2	8/30/65	30.6	18.6	13.5
165.0	7/15/64	199.1	8/22/65	34.1	20.7	13.2
165.0	7/15/64	199.6	9/ 7/65	34.6	21.0	13.7
179.0	7/15/64	209.1	7/ 9/65	30.1	16.8	11.8

Females

154.0	7/14/64	169.9	8/31/68	13.9	9.0	49.5

In Table 5 the number of sub-legal males that molted after tagging is compared with the number of legal males undergoing a molt. It is apparent that only 3 of 151 legal crab molted as opposed to 70 of 125 sub-legals, which may be taken as evidence that the molt from sub-legal to legal size is the terminal molt for most males.

Table 6 shows that of the 276 tagged crabs recovered (144 legal size, 132 sub-legal), only 3 of the legal sized groups had molted and that this had occurred in the first available May molting period after tagging. None of the recovered males tagged at legal size had molted after the second molting period and no recoveries of tagged adult males were made after the third.

From these observations it would appear that most males upon reaching legal size could be expected to live through the first year, few would survive the second year and none the third.

This determination agrees with that of Butler (1961) who worked with Dungeness crab on the north end of the Queen Charlotte Islands.

His measurements of carapace width included the 10th anterolateral spines and for comparison with data presented in this paper his data was converted using the equation:

$$y = 0.0715x - 0.029$$

in which y = the combined length in cm of 10th antero-lateral spines and x = carapace width in cm exclusive of spines. The above equation was developed by Butler from data collected by Weymouth and MacKay (1936). This conversion was checked against measurements of local specimens and was found to be very accurate.

Butler states that male Dungeness crabs reach the equivalent of 165 mm in shoulder width (legal size in S.E. Alaska) in 4 to $4\frac{1}{2}$ years, and that in one more year the majority would reach stage 15 or 194 mm shoulder width with some possibly requiring 6-7 years. Quoting Butler "Probably then males generally reach stage 15 after 5 years and live for a year longer; and even if molting is less frequent in the latter stages, the maximum age is no more than 8 years". He further states that stage 16 (225 mm shoulder width) is rarely if ever reached. This is in agreement with the largest size found in the S.E. Alaska study area of 219 mm, a rarity for this location as well.

By comparison the pre-recruit group shows an increase in the percentage of molted crabs with 56.0 percent molting after the first May, 88.2 percent after second May and 100 percent after the third May. This trend is the reverse of that observed for the legal group. The sub-legal group is

Table 5. Number of sub-legal and legal tagged male crabs recovered showing number and percent of each size class recovered.

Size class mm		Number recovered	No. molted	Percent molted
135-139		0	1	100
140-144		0	0	-
145-149	Pre-recruit	2	2	100
150-154	sub-legal	13	13	100
155-159	males	49	30	61
160-164		60	24	40
Sub-total		125	70	56
165-169		22	2	9
170-174		20	0	0
175-179		31	1	3
180-184	Legal sized	25	0	0
185-189	males	18	0	0
190-194		18	0	0
195-199		12	0	0
200-204		2	0	0
205-209		2	0	0
210-214		1	0	0
215-219		0	0	0
Sub-total		151	3	2
GRAND TOTAL		276	73	26%

Table 6. Number of tagged male crab recovered and molted at each May molting period.

Legal size crab

Recovered prior to molting period		Recovered after first molting period	Recovered after second molting period	Recovered after third molting period	Totals
Molted	0	3	0	0	3
Non-molted	32	104	5	0	141
	32	107	5	0	144

Sub-legal size crab

Molted	2	52	15	1	70
Non-molted	20	40	2	0	62
	22	92	17	1	132

apparently increasing in weight while the legal group is decreasing in numbers hence losing weight.

DISCUSSION

It is generally recognized that tagging projects may have certain limitations. One of these is that tag returns may be more of a function of the distribution of the fishery than of the migrational patterns of the stocks under investigation. This problem was minimized by tagging crabs either in an existing fishery or in locations that were surrounded by places normally fished. This increases the possibility of a recapture regardless of the direction in which the animal travels. Where tagged crabs were released in areas not normally fished a moderately successful effort was made to secure the cooperation of commercial fishermen in recovering these crabs.

The number and size distribution of molted tag recoveries was considered insufficient for detailed statistical analysis, but gave a preliminary indication of growth increments at various sizes and allowed some speculation on natural mortality of adult males.

The almost complete absence of juveniles, male and female, in areas normally fished for this species, seems to point out that an entirely different approach may be necessary to acquire growth information on this group. The stomach contents of 90 Dungeness crab were examined and pieces of shell from juvenile Dungeness crab were found in some of the stomachs. This probable cannibalism by adults on younger crab may be the reason that juveniles were generally not found in abundance on grounds containing quantities of adults.

In retrospect it is apparent that the foregoing study was too wide spread geographically to give other than preliminary indications of stock boundaries. It appears, however, that the project enhances the possibility of describing the geographic boundaries in Southeastern Alaska of various stocks of Dungeness crab with a minimum of tagging, providing sufficient information on local habitat is collected. The habitat in this area is sufficiently discontinuous to make this approach practical.

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PART II. A STUDY OF THE GROWTH AND MOLT PATTERNS OF THE ADULT DUNGENESS CRAB (Cancer magister Dana) in SOUTHEAST ALASKA

By

Oliver S. Osborn

INTRODUCTION

A growth study was conducted on the Dungeness crab in Southeast Alaska during the years 1965 through 1969 by the Alaska Department of Fish and Game. Similar studies were performed by Butler (1961) in British Columbia, and Poole (1965) in California.

The original investigator, Mr. Carl Lehman, terminated his work on this project before it was brought to completion. The author is responsible only for attempting to organize and present such portions of the data as seem important. The author had very little contact with the field work done by the original investigator.

The objectives of this segment of the study were as follows: (1) To determine growth and molt patterns in the Southeast Alaska area, and (2) To estimate the size of a population of crabs existing in a known area.

GROWTH AND MOLTING PATTERNS

Materials and methods

The study was conducted in Southeast Alaska in two areas south of Petersburg. Duncan Canal on Kupreanof Island was utilized during 1965 and 1966. St. John's Harbor on Zarembo Island was the study site during 1967, 1968, and 1969. The two areas are separated by Sumner Strait, which is between 50 and 70 fathoms deep and about 5 miles wide at this point. Most of the following observations are based on the St. John's Harbor tagging, however, data on molt timing from both areas will also be included.

Capture of crabs was by crab pot. Twenty pots were used, built on the standard round, 65 pound Dungeness crab pot frame, with 1 inch by $1\frac{1}{4}$ inch mesh, six triggers on each tunnel, and no escape ring. The M/V SHEARWATER, a 40-foot Alaska Department of Fish and Game vessel equipped with hydraulic lifting gear was used to fish the pots. The pots were hauled as often as twice a week during good weather and at least once every two weeks during unfavorable weather. No trips were made in November and December of 1967, January and November of 1968, and January and April of 1969.

The design of the study was capture-recapture of tagged crabs. Five thousand two hundred and fifty crabs were tagged with a plastic spaghetti tag inserted through two holes punched along the demersal line of the carapace at the posterior of the crab. The two ends of the tag were tied leaving a loop through the two holes and two easily discernible pigtails. This tag is retained through molting, allowing measurement of crabs before and after the molt. This method was used by Butler (1957, 1961) and Poole (1965).

For growth data, tagged and previously measured crabs were remeasured as recaptured, with stainless steel vernier calipers to the nearest one-tenth millimeter. Each measurement was taken across the back just anterior to the tenth anterolateral spines.

Results

Growth per molt

Two hundred and thirty tagged males and 67 tagged females were recaptured after having molted. The data is summarized in Tables 1 and 2.

Width after molting was plotted as a function of width before molting. These points were fitted by the least squares method to a straight line of the general form:

$Y = aX + b$ where Y = carapace width in mm after molting

X = carapace width in mm before molting

a and b = fitted constants

The following equations were obtained:

for adult males (X = approximately 100 to 180 mm):

I. $Y = .943X + 36.6$

for adult females (X = approximately 90 to 160 mm):

II. $Y = .924X + 27.8$

Table 1. Average increase in carapace width of tagged male Dungeness crab resulting from one molt. St. John's Harbor, Alaska.

Size range in mm	Number of observations	Carapace width		Increment	
		Old	New	Absolute	Percent
120-124	2	122.5	147.5	25.0	20
125-129	6	126.7	155.5	28.8	23
130-134	9	132.6	161.6	29.0	22
135-139	13	136.9	163.3	26.4	19
140-144	11	142.8	169.8	27.0	19
145-149	23	147.2	175.2	28.0	19
150-154	33	152.2	180.2	28.0	18
155-159	64	157.2	185.4	28.2	18
160-164	51	162.0	189.9	27.9	17
165-169	11	165.8	193.8	28.0	17
170-174	4	172.8	199.5	26.7	16
175-179	2	177.5	207.5	30.0	17

Table 2. Average increase in carapace width of tagged female Dungeness crab resulting from one molt. St. John's Harbor, Alaska.

Size range in mm	Number of Observations	Carapace width Old	Carapace width New	Increment Absolute	Increment Percent
50- 54	1	51.0	65.0	14.0	27
85- 89	1	89.0	106.0	17.0	19
100-104	1	100.0	113.0	13.0	13
105-109	0	-----	-----	----	--
110-114	2	113.0	130.0	17.0	15
115-119	8	116.9	132.4	15.5	13
120-124	1	120.0	138.0	18.0	15
125-129	6	126.5	146.3	19.8	16
130-134	12	132.5	149.7	17.2	13
135-139	14	137.1	153.9	16.8	12
140-144	12	141.7	158.5	16.8	12
145-149	6	146.2	160.5	14.3	10
150-154	3	151.7	167.7	16.0	11

The results are shown in Figure 1. The dotted lines show Butler's (1961) results for comparison. Butler took his measurements including the tenth anterolateral spines. Poole (1965) gives an equation derived by H. G. Orcutt for converting measurements to include or exclude the spines for crabs larger than 100mm. The equation is:

III. $Y = 3.727 + 0.0465X$ where Y = carapace width in mm including spines

X = carapace width in mm excluding spines

The relationships shown in Figure 1 are based on growth increment rather than absolute carapace width. Since the spine correction is nearly a constant for the large crabs (100 to 200 mm) it has very little effect on growth increment where the old shell spine length subtracts from the new shell spine length.

Using equation III to convert points from Butler's data (Butler, 1961) into measurements excluding the spines confirms the fact that the line as given by Butler and shown in Figure 1 would not be changed significantly through conversion. Therefore, it is a useful comparison to the growth data reported here.

Although effort was expended on gathering data on small crab growth (carapace width 0 to 90 mm) the results were judged by the author to be inconclusive and are not presented here. However, the author believes that the growth of these crabs would approximate that found by Butler (1961). Butler indicates that crabs reach the 90 to 110 mm width after two years. If so, then using either Butler's data or the data reported here, and assuming an annual molt, after the third year the males would be in the size range 120 to 140 mm and after the fourth year would be in the range 140 to 170 mm. The females would range in width from 90 to 110 mm after two years, from 110 to 130 mm after three years, and from 130 to 150 mm after four years.

Molt frequency

Tables 3 and 4 show the pattern of molting of 335 recaptured male crabs and 179 recaptured female crabs. The recaptured crabs are separated by the following: 1) Molted before recapture. 2) Recaptured after one year without molting. 3) Recaptured after at least two years without molting.

Recaptured males molted annually up to the size range of 155 to 160 mm in carapace width. Recaptured crabs larger than this began to molt less frequently. Of the crabs recaptured in the minimum legal size range (165

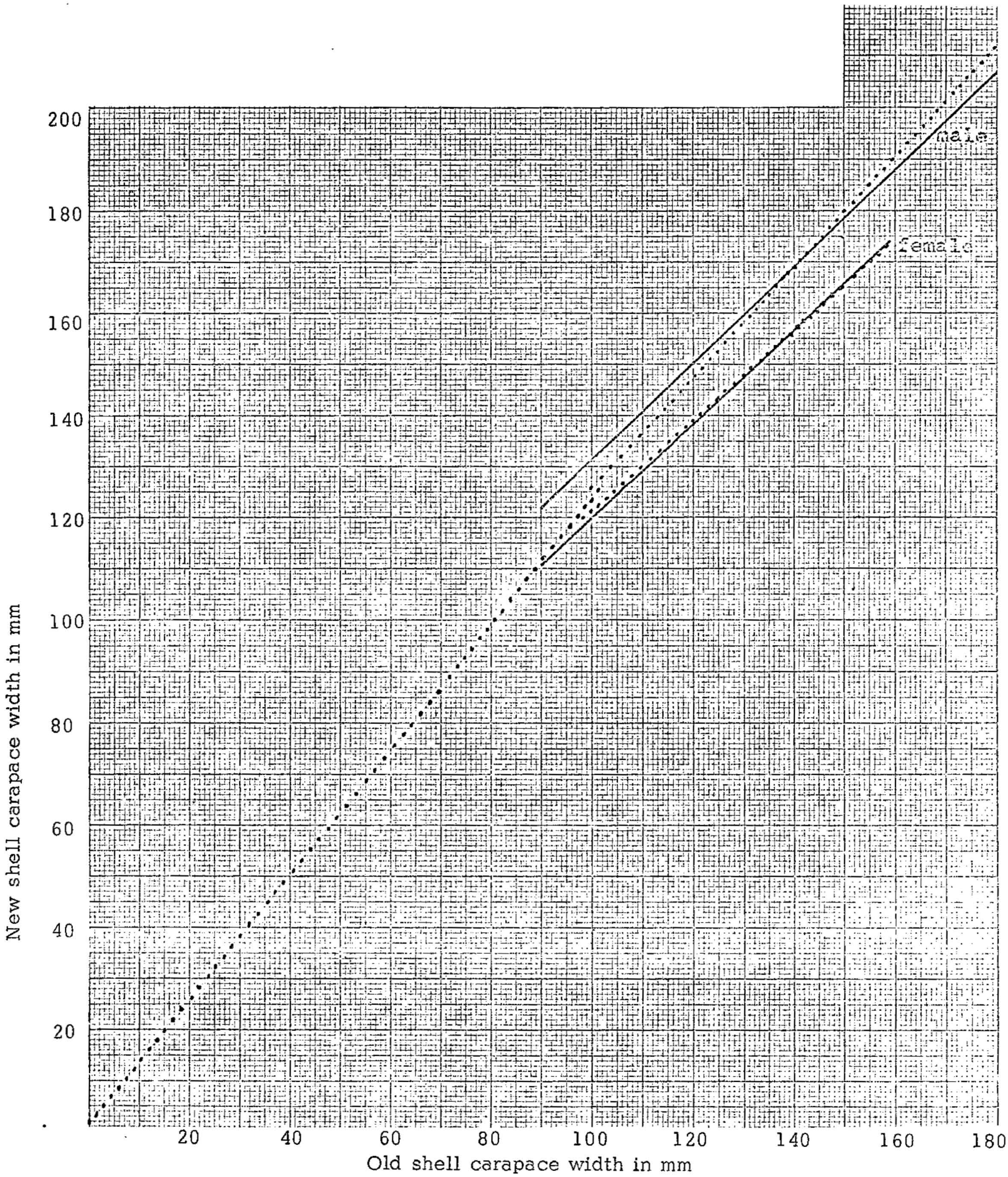

Figure 1. Increase in carapace width per molt of adult Dungeness crab in Southeast Alaska (dotted line shows data reported for British Columbia (Butler, 1961)).

Table 3. Frequency of molting of 335 recaptured male Dungeness crab by carapace width in mm excluding spines.

Size class (carapace width in mm)	Molted before recapture		Recaptured after 1 year without molting		Recaptured after 2 year without molting	
	No.	Percent	No.	Percent	No.	Percent
130-134	3	100	-	-	-	-
135-139	3	100	-	-	-	-
140-144	1	100	-	-	-	-
145-149	3	75	1	25	-	-
150-154	2	100	-	-	-	-
155-159	10	59	7	41	-	-
160-164	4	17	19	79	1	4
165-169	3	6	43	90	2	4
170-174	1	2	38	88	4	9
175-179	1	2	52	85	8	13
180-184	-	-	42	86	7	14
185-189	-	-	35	81	8	19
190-194	-	-	23	92	2	8
195-199	-	-	11	100	-	-
200-204	-	-	1	100	-	-

Table 4. Frequency of molting of 179 recaptured female Dungeness crab by carapace width in mm excluding spines.

Size class (carapace width in mm)	Molted before recapture		Recaptured after 1 year without molting		Recaptured after 2 year without molting	
	No.	Percent	No.	Percent	No.	Percent
130-134	11	92	1	8	-	-
135-139	12	71	5	29	-	-
140-144	11	26	31	74	-	-
145-149	6	17	29	83	-	-
150-154	1	3	31	94	1	3
155-159	-	-	28	87	4	13
160-164	-	-	4	80	1	20
165-169	-	-	2	100	-	-
170-174	-	-	1	100	-	-

-169 mm), 94 percent did not molt annually. Females begin to show a similar drop in molt frequency in the 145-155 mm size range.

Molt timing

Table 5 shows the percent occurrence by month of soft-shelled male crabs in St. John's Harbor and Duncan Canal. The data indicated that some Dungeness crab molted in any month of the year with most molting occurring between February and May, and with the largest group molting in April.

Table 6 show the percent occurrence of egg clutches on female Dungeness crab in St. John's Harbor and Duncan Canal. The eggs are apparently extruded in the fall during September and October. These eggs are carried through the winter and disappear in the spring, indicating hatching. The female must molt in order to produce fertile eggs the next fall, which would indicate summer molt and breeding before the eggs appear in the fall. This matches the description of the Dungeness crab of Queen Charlotte Islands (Butler, 1956, 1961).

Discussion

The growth rate found for Southeast Alaska can be compared with that calculated by Butler (1961) for British Columbia and by Poole (1965) for California. Figure 2 shows the growth curves of the three areas. It was necessary to assume that the first two years of growth in Southeast Alaska matched that found by Butler for northern British Columbia.

Butler's data is corrected by the formula described previously to exclude the spines.

The growth rates for all three areas show very little difference. The California data indicates the crabs grow faster during the first two years than in British Columbia, but after that grow slightly slower. Growth in Alaska from the second year shows the same rate as California. Error may have been introduced into the British Columbia growth rate due to the necessity of using a conversion factor.

The data on molt frequency is rather limited, yet it has important implications. No males less than 144 mm in carapace width were observed to pass a year without molting. Conversely, no male of more than 179 mm was observed to molt within one year of release. The pre-recruit size class is made up of the male crabs which will attain legal size during their next molt. This is the range from 140 to 165 mm. Of 48 male crabs observed in

Table 5. Occurrence of soft-shelled male Dungeness crab. Includes years 1965 and 1966 in Duncan Canal, and years 1967, 1968, and 1969 in St. John's Harbor.

Month	Number of crabs examined	Number of soft crabs	Percent soft crabs
January	No data	No data	No data
February	128	7	5.5
March	73	3	4.1
April	74	9	12.2
May	900	39	4.3
June	677	6	0.9
July	1,034	82	7.9
August	1,345	9	0.7
September	849	4	0.5
October	390	2	0.6
November	319	2	0.6
December	129	2	1.6

Table 6. The occurrence of egg clutches on female Dungeness crab in St. John's Harbor and Duncan Canal.

Month	Total crab	Number crabs with eggs	Percent crabs with eggs
January	--	--	--
February	51	6	11.8
March	32	4	12.5
April	7	0	0.0
May	782	6	0.8
June	1,296	4	0.3
July	1,764	4	0.2
August	1,457	1	0.1
September	693	35	5.5
October	357	66	18.5
November	232	87	37.5
December	41	15	36.6

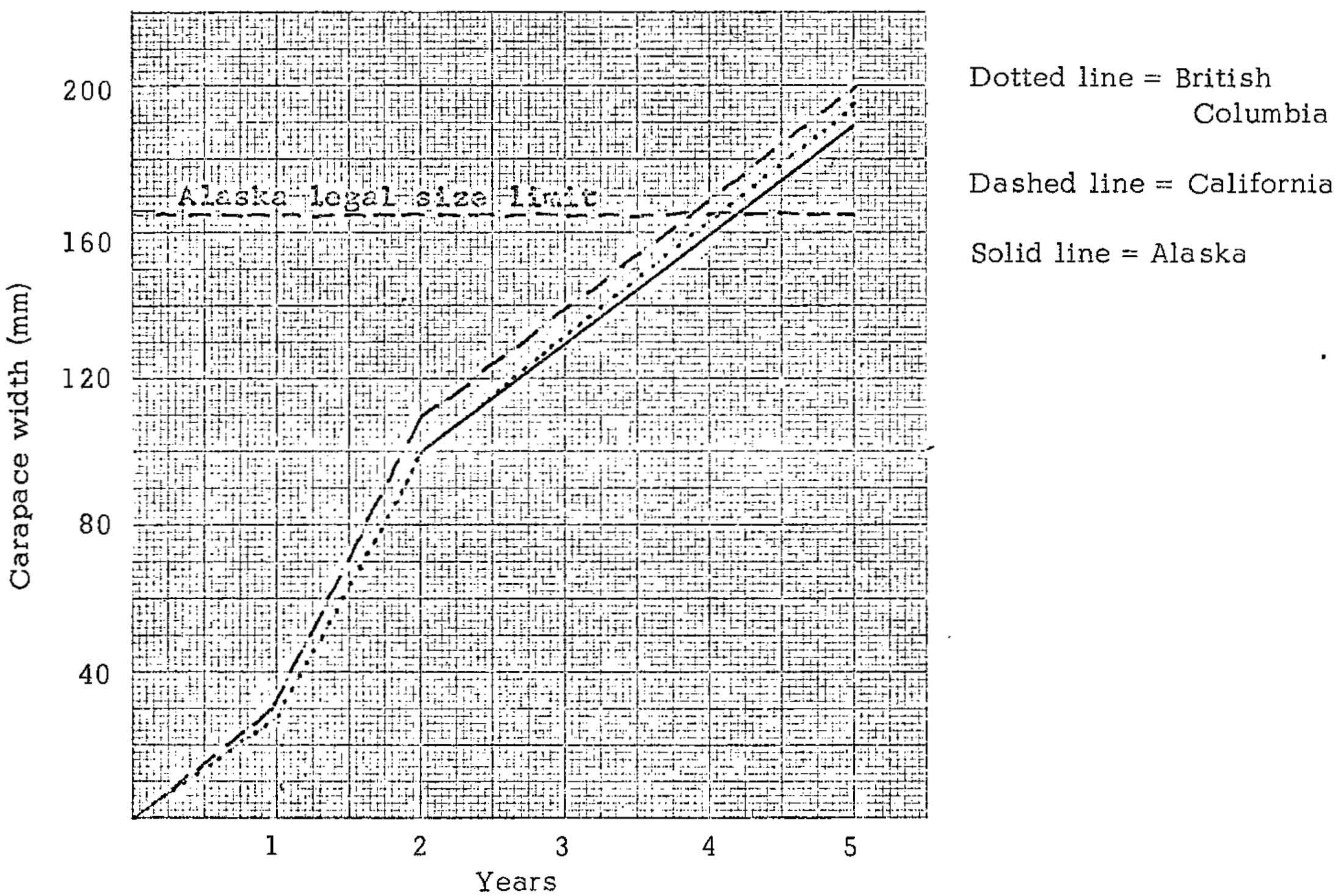

Figure 2. Comparative growth curves for California (Poole, 1965), British Columbia (Butler, 1961), and Southeast Alaska. (Due to lack of data, the first 2 years of growth in Alaska is assumed to match that of British Columbia.)

this size range, 42 percent molted within a year, 56 percent did not molt within one year, and 2 percent did not molt within two years. Of crabs which are just legal (165-169 mm), 48 were observed of which only 6 percent molted within one year, 90 percent did not molt within one year, and 4 percent did not molt within two years.

These data indicate a sharp drop in molt frequency, and thus in growth rate, at very nearly the size which male crabs become legal. Figure 2 does not compensate for the drop in molt frequency as males attain legal size. Thus in fact, the growth curve will begin to level out as the carapace width goes above 155 mm.

For females, the first size class where the crabs not molting within one year outnumber the molting crabs is the 140-144 mm carapace width range. Of 42 crabs, 74 percent did not molt within a year. Butler (1960) describes the breeding habits of Dungeness crab. He writes "The male finds a hard-shelled female and holds her until she molts." Also, "soon after the shell of the female is cast, copulation occurs." If hard-shelled females cannot be fertilized, then the occurrence of females not molting within a year indicates a decrease in the reproductive potential of the size group. This seems to occur in female crabs of 140 mm carapace width and above.

POPULATION ESTIMATE: ST. JOHN'S HARBOR

In conjunction with the growth and molting study an attempt was made to estimate the population size of assumed isolated population of crabs in St. John's Harbor utilizing the multiple release and recapture method. No commercial fishery was being conducted in the area at the time of the study.

Methods

After each trip to St. John's Harbor, a population estimate was made based on the tagged-untagged ratio of the crabs caught in the special pots described above in the section on growth and molting. Utilizing the tagged to untagged ratio provided by the pot captures, a continuous ratio was obtained as the experimental fishing proceeded. It was hoped that eventually most all of the crabs would be tagged thus providing increasing accuracy of the estimate.

The size of a population involved in a capture-recapture study may be estimated through the use of ratios. If the total number of tagged crabs in the population distribute themselves randomly, then the ratio of the tagged crabs in any recaptured sample to the total amount of tagged crabs in the population, should be equal to the ratio of the total tagged plus untagged crabs in the recaptured sample to the total number of crabs in the population.

Thus: $Y = \frac{A}{B} \quad (X)$

Where: A = Number of tagged crabs in the recaptured sample

B = Total number of tagged crabs in the population

X = Total number of tagged and untagged crabs in the recaptured sample

Y = Total number of crabs in population

The assumptions made are:

1. That the tags and/or pots fished are randomly distributed throughout the population.

2. That tags are not selected for in recaptures.

3. That there is no differential mortality.

4. That there is no emigration or immigration.

A further refinement was possible as each crab caught was examined prior to release. A crab observed to have the tag missing was retagged so as not to exagerate tag loss upon subsequent recovery of that crab. As the retagged crab was not an addition to the tagged population, but a replacement, it was taken into account when calculating the number of tags at large. Tagged crabs that were found to be dead upon capture were subtracted from the total tagged population at the time of capture. These two procedures were an aid in avoiding over estimates of the population.

The 20 pots that were fished to provide these estimates were moved frequently in a random fashion over the fishable grounds in order to insure that all portions of the population received an equal opportunity to be sampled.

Results

The size of the Dungeness crab population of St. John's Harbor has been estimated for each sample of crabs caught in 1968 and 1969. The estimates are shown listed in Table 7. In many cases the sample size is too small to be reliable, and extreme estimates are produced. If only those samples are considered where at least 40 crabs of each sex are captured, the estimate stabilizes close to 4,500 for males, 12,000 for females, and 16,500 for total crabs. Ranges, however, are wide with figures for males from 3,162 to 16,353, for females from 6,552 to 44,880, and for the total population from 10,705 to 50,676.

Discussion

There seems to be a directional trend in the population estimate with the estimate seemingly to increase and then decrease during the study. This may reflect actual population trends or may result from the method of investigation. Tags will have been removed from the population through actual tag loss, through natural mortality, and emigration of tagged crabs. Tag loss is difficult to compensate, for with correction possible only for crabs found dead in the pots or those recaptured crabs showing an obvious tag loss through the presence of holes in the carapace through which the tag had been threaded. As previously mentioned, dead tagged crabs were subtracted from total tagged crab figure and those individuals having obviously lost their tags were retagged. Uncorrected tag loss would result in an inflated population estimate with the reverse occurring when tagged crab are over represented in the recaptured samples.

The validity of the population size estimates can be criticized from several viewpoints. One problem is the assumption that immigration and emigration were both insignificant. Another is that the population was homogenous with complete mixing of tagged and untagged crabs. Finally, once-captured crabs may have become conditioned to the pots either positively or negatively.

Table 7 . Population estimates -- St. John's Harbor.

Date	Tags Recaptured Male	Tags Recaptured Female	Tags in Pop. Male	Tags in Pop. Female	Untagged Captures Male	Untagged Captures Female	Population Estimates Male	Population Estimates Female	Population Estimates Total
2/14/68	3	0	1,552	2,038	8	2	5,691	--	15,556
2/20-21/68	24	4	1,551	2,038	30	23	3,490	13,756	10,382
3/5/68	13	2	1,577	2,059	18	7	3,760	9,265	9,696
4/10-11/68	28	6	1,593	2,065	50	7	4,437	4,474	9,790
5/14-15/68	23	7	1,631	2,070	42	18	4,609	7,392	11,103
5/21/68	38	18	1,659	2,088	59	61	4,234	9,164	10,705
6/26-27/68	44	11	1,639	2,142	56	49	3,725	11,683	10,999
7/9/68	62	31	1,678	2,183	61	125	3,329	10,985	11,583
7/24/68	51	38	1,725	2,283	74	136	4,227	10,453	13,465
7/30/68	29	35	1,797	2,410	34	147	3,904	12,532	16,104
8/5/68	22	26	1,812	2,509	49	92	5,847	11,387	17,013
8/14/68	32	30	1,738	2,491	61	75	5,042	8,718	13,505
8/21/68	22	9	1,793	2,564	32	14	4,401	6,552	10,400
8/27/68	22	12	1,824	2,578	36	61	4,809	15,682	16,961
9/10/68	21	28	1,857	2,638	37	151	5,129	16,864	21,741
10/25/68	54	22	1,856	2,635	38	60	3,162	9,821	11,839
12/5/68	31	12	1,849	2,628	47	30	4,652	9,198	12,493
2/26/69	25	2	1,842	2,620	43	9	5,010	14,410	19,420
3/6/69	1	1	1,837	2,618	42	22	78,991	60,214	139,205
5/15/69	1	1	1,837	2,618	10	7	20,207	20,944	41,151
5/21/69	2	0	1,836	2,618	8	11	9,180	---	---
5/26/69	10	1	1,836	2,618	68	25	14,320	68,068	82,388
6/17/69	17	4	1,895	2,640	35	64	5,796	44,880	50,676
6/27/69	6	5	1,922	2,695	45	53	16,353	31,331	47,684
7/14/69	13	8	1,960	2,719	21	18	5,139	8,860	13,999
7/24/69	8	6	1,960	2,716	18	25	6,386	14,084	20,470
7/31/69	13	12	1,960	2,714	36	46	7,406	13,175	20,581
8/7/69	21	5	1,960	2,711	29	39	4,679	23,988	28,667
8/21/69	14	6	1,959	2,708	31	22	6,313	12,721	19,034
8/28/69	19	21	1,957	2,707	33	119	5,375	18,172	23,547
9/3/69	14	25	1,957	2,698	43	126	7,996	16,465	24,461
10/7/69	20	23	1,955	2,689	43	69	6,168	10,584	16,734
10/16/69	18	6	1,953	2,679	25	17	4,689	10,438	15,127
10/24/69	15	5	1,953	2,677	18	5	4,318	5,446	9,764
11/7/69	8	3	1,950	2,676	23	5	7,603	7,261	14,864

* Population estimates based on a minimum of 40 crabs for each sex captured.

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PHASE II. EFFECTS OF LOG STORAGE ON THE DUNGENESS CRAB FISHERY IN SOUTHEASTERN ALASKA

By

Carl Lehman

Concern has been expressed by various commercial Dungeness crab fishermen regarding the effects of log rafting and dumping areas on previously utilized crab fishing grounds. A preliminary study based on a minimum of observations made as time permitted, was initiated in April 1966 to determine if any basis existed for the expressed concern. Tentative objectives for the study were as follows:

1. To examine existing log rafting and dumping areas and observe bottom conditions after known use.

2. To examine proposed dumping areas prior to use, and during use, in an attempt to relate bottom changes to time.

After discussion of the proposed study with a representative of the U.S. Forest Service (USFS) selection of Hamilton Bay as a study area was made.

METHODS

Pre-reafting area

In October 1966 a trip was made on the USFS vessel M/V CHUGACH to Hamilton Bay for the purpose of describing the general physical and biological conditions on the bottom prior to log rafting activities. SCUBA gear was employed in this examination with re-examination to be performed after logging.

A series of four transects was laid out across the lagoon each of which was 300-400 feet long and included depths to forty feet. A length of polypropyline line was stretched across the lagoon at each transect. A man aboard a skiff moved along each line and measured off 20 foot intervals thus establishing a total of 79 transect stations.

Visual observations were made and recorded at each station with photographs taken of the bottom as conditions warranted. Observations included bottom type (gravel, boulders, silt, sand, etc.), and the percent of bottom covered by plants, sessile fauna and detrital material. A check list was kept of flora and fauna observed on the bottom of the lagoon. Samples of bottom sediments were taken by scooping up portions of the bottom with a quart jar.

Post rafting areas

Employing SCUBA and the same procedures outlined above several log rafting and storage areas were examined that had been in use for various lengths of time. In addition, Hamilton Bay was re-examined in February 1970 after its initial pre-rafting examination in October 1966.

RESULTS

Pre-rafting

The examination of the Hamilton Bay log rafting area prior to use by the logger demonstrated the sample area to be covered by a scattering of detritus (at the rate of less than 1 %) consisting of bark, twigs, conifer needles, and associated materials. The same SCUBA observation indicated Dungeness crabs to be numerous through actual sightings and by the density of "crab tracks" across the bottom.

Bottom samples were collected and subsequently analyzed for percent nitrogen (by the Kjeldahl method), percent organic matter (weight loss on ignition), and for pH, by Paul E. Heilman at the University of Alaska.

Meaningful information from such bottom sampling was scanty since considerable calcium carbonate was present in these sediment samples, thus rendering unreliable those determinations on total carbon and weight loss on ignition. Results of the pH determinations were almost neutral ranging from values of 6.75 to 7.80 with an average of 7.14. Such values were expected since salt water is well buffered. Determinations, however, were completed in an effort to allay the fears of local crab fishermen that the presence of quantities of hemlock bark might result in an acid condition.

Underwater photographs proved of little value. High turbidities precluded satisfactory delineation of bottom features.

In April 1967, Hamilton Bay was examined for the second time prior to log rafting activities. Transects 3 and 4 were examined with no change noted since the original examination in October 1966 other than the normal spring growth of seaweeds such as Hedophyllum and a layer of filamentous yellow-green algae.

Post-rafting

In February 1970, the Hamilton Bay log rafting and storage area was re-examined with the aid of SCUBA gear. Transect lines 1 and 2 showed only a minimal build-up of bark and debris, but these two transect lines were outside the borders of the actual dump area. Lines 3 and 4, however, showed definite increases in bark and associated log-rafting debris (Table 8).

Table 8. Percent log-rafting debris present by transect line before and during use at Hamilton Bay.

Dates	Line 1	Line 2	Line 3	Line 4
April 1967	0.05	1.05	0.17	3.28
February 1970	4.30	2.56	68.93	25.75

At Hamilton Bay a slight current of approximately 0.5 to 1.0 knots was noted in the log-rafting area flowing in one direction at the surface and in the opposite direction at the bottom. There is some evidence that this current combined with quantities of silt is covering the logging debris as it falls to the bottom, particularly during periods when the rafting area is inactive. Bark, twigs, and boom-stick borings were found 6 inches deep below the surface layer of silt- a condition not observed on previous visits to the area. Under these conditions there was little observable decrease in the Dungeness crab population in the log-rafting area. To what extent this is due to the silt cover over the rafting debris is not known. Several specimens were sighted and captured, and trails left by the species were not uncommon. An indication, however, of possible future problems was present. Due to the oxidation of organic materials, an anaerobic situation appears to be developing in bottom samples that was not previously present. Due to the press of other business bottom sample analysis performed during the pre-rafting stage was not repeated.

Underwater examination of log-dumps in areas other than Hamilton Bay was also undertaken. An area near the mouth of the Patterson River in Thomas Bay that had been in use for 12 years was examined in April 1967. At the time of the survey the tide was approximately 4 hours out and the current through the rafting area was running at about 4 knots. The bottom under this area was quite free of accumulated bark and debris, and Dungeness crabs were found in molting condition directly under the dump.

Two other areas of smaller dimensions and shorter duration as log-dumps, were examined in Thomas Bay. Both were relatively free of rafting debris.

One more log-rafting area was examined in Halleck Harbor, Saginaw Bay, Kuiu Island, on April 27, 1967. This dump has been in existence since May 1964. There is virtually no current in Halleck Harbor.

SCUBA observations directly under the working area showed the bottom to be covered by 3 to 4 inches of accumulated bark and debris. No Dungeness crabs were observed within the debris covered area, although kelp crab (Oregonia gracilis) were present in abundance. Observations made immediately outside the rafting area borders disclosed numerous female Dungeness to be present.

DISCUSSION

The scanty observations made during this preliminary study have shown that the physical presence of bark and associated debris on the substrate mechanically reduces the suitability of the habitat for Dungeness crab. This mechanical effect is greatest in the immediate log-rafting area, and in the absence of strong current. When strong currents are present log-rafting debris is swept away and therefore has little effect upon the crab population in the immediate vicinity. What happens in the area where such debris is eventually deposited, or to the marine animals in such an area, is not within the scope of this study.

RECOMMENDATIONS

Few recommendations should be expected from a preliminary investigation of this nature. Probably the best method of keeping log-rafting debris off Dungeness habitat is to keep logs out of the water and to barge them to their final destination.

The next suggested improvement would be to lift logs from trucks for placement in the water rather than dumping onto a ramp and allowing them to slide or roll into the rafting area. Less bark and debris would be loosened or knocked from logs with such treatment.

A third consideration would be the locating of rafting areas over grounds unsuitable for Dungeness crab, or subject to strong currents. This method, however, appears a temporary expedient at best, and leaves unanswered possible questions. For example, is it sufficient to hide log-rafting debris by sweeping it out of sight with strong currents? What damage, if any, occurs in deeper water crab habitat where rafting debris must eventually become deposited? The "solution to pollution" may be dilution, but where does dilution end?